PHYSICAL CHANGES IN GLASS BATCHES AS AFFECTED BY HEAT TREATMENT

BY

WILLIAM ARTHUR GRAFF

B.S., University of Illinois, 1946
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AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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CERAMICS IN THE GRADUATE SCHOOL OF
THE UNIVERSITY OF ILLINOIS, 1949

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ACKNOWLEDGEMENT

The author wishes to express his appreciation to Professor F. V. Tooley for the supervision and advice given during the course of this investigation. Furthermore the author would like to express his appreciation to Dr. A. I. Andrews, Head of the Department of Ceramic Engineering, for the advice and encouragement he has given.

Acknowledgement is also made to the Owens-Illinois Glass Company for providing the fellowship under which this investigation was conducted.

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PHYSICAL CHANGES IN GLASS BATCHES AS AFFECTED BY HEAT TREATMENT

In recent years it has become apparent that substantial improvement of the glass manufacturing process in large volume production is dependent upon a more detailed understanding of the many controlling variables.

The phase of the manufacturing process which was of primary concern in this investigation was the initial physical change occurring in the raw batch upon subjection to heat. Some work concerning glass melting has been conducted and affords a preliminary understanding of the process in terms of the types of reactions involved. However, this theoretical work is ineffiective and unavailing in useful application to the melting process.

The aim of this investigation was to study the early consolidation behavior of a soda-lime-silica glass batch in terms of the primary variables of composition, grain size distribution, time and temperature.

An experimental procedure was adopted which gave reproducible results for batch consolidation following heat treatment. The heat treatments were made on 50 gm. batches contained in a rectangular Inconel receptacle; a Glo-bar furnace was used as the heat source. Following heat treatment and cooling to room temperature, consolidation of the batch was evaluated by the mechanical process of agitation and screen analysis.

For purposes of interpreting results in terms of the industrial melting process, only industrial grade raw materials were used. These were Ottawa glass sand, dense soda ash and calcite limestone. On a basis of grain size distributions of these raw materials, about 85-90% by weight of a typical batch is smaller than 40 mesh (U. S. S.). Since the material smaller than 40 mesh was considered as being susceptible to dusting loss, the 40 mesh screen was adopted as the definition between consolidated and non-consolidated batch. Consolidation was then expressed as the percent by weight of the heat treated batch that was retained on a 40 mesh screen.

The experimental work was carried on with a view of determining:

1. The effect of composition of a fine-grained batch on the consolidation produced by heat treatment.

2. The effect of composition and concentration of a relatively fine-grained minor component on the consolidation when the major component of the batch was coarse material.

3. The effect of time and temperature of heat treatment on the consolidation produced in a typical soda-lime-silica glass batch.

The limits of compositions studied varied from 0-75% sand, 5-85% soda ash and 10-65% limestone. Batches were made up of —100+200 mesh material screened from the indicated raw materials. Average consolidations were determined for 41 compositions following two minute heat treatments in a furnace held at 1000°C. and 1100°C. These average values were used to plot lines of iso-consolidation in the sand-soda ash-limestone system.

General trends of the iso-consolidation lines indicated that the sand exerted the controlling influence regardless of the soda ash to limestone ratio. Following any constant soda ash to limestone ratio, as the sand content increased the consolidation decreased to a minimum and then increased slightly. The minimum consolidation of about 10% for the 1000°C. and 20% for the 1100°C. treatment was observed in the range of 50-60% sand. Maximum consolidation observed in the composition range studied occurred for high soda ash-limestone batches and produced values of about 45% and 70% for the respective heat treating temperatures.

Evidence of carbon dioxide retention in the batches, the lack of correlation with phase relations in the oxide system and the ease of melting of the carbonates at heat treating temperatures indicated that the consolidation process was controlled by reactions involving the original carbonates in the batch. Extent of the process was dependent on the quantity of glassy phase developed and the distribution of the glass with respect to the sand grains.

The slight increase in consolidation in the higher sand content batches was attributed to an increased ratio of sand grains to carbonate grains. Thus on heat treating, even though the quantity of glass formed was less in the higher sand batches, the glassy matrix was distributed between the sand grains such that a denser, stronger structure resulted.

In order to observe if the consolidation behavior of a specific fine-grained composition was characteristic in a batch containing larger sized grains, nine compositions were selected from the composition study to represent the fine-grained (—100+200 mesh) component in a typical batch. These components were added as a 10% and 20% concentration by weight in a complete batch composed of 62% sand, 20% soda ash and 18% limestone. The coarse-grained material was the —40+60 mesh fraction of the raw materials. Heat treatments for this phase of study were for two minutes in a furnace held at 1100°C. and 1300°C.

No definite trend in consolidation behavior was caused by changes in the composition of the fine-grained component. Furthermore, the fine-grained concentration indicated no significant influence on consolidation as compared to that produced in a batch of typical commercial grain size distribution by the same heat treating conditions. This reference batch produced consolidations of 50% and 84% respectively for the heat treatments at 1100°C. and 1300°C. Compared to these values, batches containing a 10% fine concentration indicated consolidations in the ranges of 47-53% and 83-90% for the two heat treatments, while for a 20% concentration of fine material the ranges were 47-53% and 77-87%. These results indicated that the larger sized grains were controlling the consolidation process.

Batches composed of 62% sand, 20% soda ash and 18% limestone and having a typical commercial grain size distribution were heat treated at temperatures between 1000°C. and 1300°C. for various times from one minute to the time necessary to approach 100% consolidation. These results indicated that a 90% consolidation was produced at 1300°C. about 2.2 times faster than at 1000°C. Based on the results of this investigation, predictions of the consolidation in a typical soda-lime-silica glass batch can be made in terms of time and temperature of heat treatment.

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VITA

William Arthur Graff was born December 25, 1923, in Highland, Illinois. He received his elementary and high school education in the public schools of that city graduating in June of 1941. In the fall of 1941 he entered the College of Engineering at the University of Illinois. On December 2, 1942, he enlisted in the Army of the United States on a reserve status, and after serving eight months on active duty was honorably discharged on November 23, 1943. Following his discharge he continued his education at the University of Illinois receiving a Bachelor of Science degree in Ceramics in February 1946. He then held the position of special research assistant in ceramic engineering at the University of Illinois from February 1946 to September 1947, during this period working toward a Master of Science degree which he received in August 1947. In September 1947, he was appointed to the Owens-Illinois Glass Company Graduate Fellowship in Ceramic Engineering.

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PUBLICATION:

W. A. Graff and A. E. Badger, "Viscosity of Glass as Affected by Dissolved Gases", *Physical Review,* Vol. 70 (3, 4), p. 220 (1946).